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Research Article

Insecticide Use Pattern and Residue Levels in Cabbage *(Brassica Oleracea Var capitata L.)* within Selected Farms in Southern Ghana

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Abstract
A survey was carried out at three localities, within Accra suburbs and Mampong-Akuapem in Eastern region of Ghana to determine insecticide use pattern in cabbage farms. Selected cabbage heads were analysed to determine the levels of insecticide residues. Residues of chlopyrifos-methyl, pirimiphos-methyl and pyrethroids (Cypermethrin, lambda-cyhalothrin and deltamethrin) were estimated on cabbage samples, using brine shrimp lethality testing after fractionation of the insecticides residues using solid phase extractor (SPE). The results of the survey confirmed findings in previous studies of over dependence of cabbage farmers on insecticides for the control of the diamondback moth (DBM) *Plutella xylostella* Linnaeus (Lepidoptera: Yponomeutidae). The residue levels of chlopyrifos were found to range from 55-124 which is above the recommended 1 mg/kg MRL. While Pyrethroid residues were not only above the recommended MRL but 12-18 fold increase was recorded compared to findings by [30]. The residue levels of pirimiphos-methyl ranged between 2.1 mg/kg and 14.6 mg/kg, which gave 2-15, fold increase above the recommended MRL of 1mg/kg. The survey revealed that inappropriate agronomic practices by cabbage farmers were the main causes of insecticide residues in cabbage. Urgent measures should be taken to educate farmers on the proper use and handling of insecticides without compromising on human health.

Keywords
survey — cabbage — insecticides — bioassay — residue

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Content

Introduction

Hazards caused by the prolonged use of pesticides may affect human health, directly and indirectly through residues in food and other biotic systems [27]. Awareness and concern about perceived risks that potential residues of pesticides may pose on human health is challenging the agro-industry worldwide especially the fruit and vegetable industry, to minimize pesticide residues in food [17]. Each year 25 million people, from the Southern hemisphere, are poisoned through occupational exposure to pesticides; out of which 220,000 die [21]. To protect the health of consumers, most developing countries rely on international standards, established jointly by (FAO) and (WHO) through Codex Alimentarius Commission [17] which have since 1961 set maximum residue limits (MRL) for pesticides in foods as well as "maximum acceptable daily intake" (ADI) value [14].

Cases of pesticide residues violation have been reported worldwide [13] reported that 2.5 billion pounds of pesticides are being applied to agricultural products each year in the

United States. This is 10 times more than was applied 40 years ago. Moreover each year there are 10,000 pesticide related poisonings. For example, on July 4^{th} 1985, over 300 Californians became sick after eating watermelons treated with the pesticide TENIK [13]. Besides 44% of vegetable crops (carrots, tomatoes and lettuce) tested in supermarkets were found to have some traces of pesticide residue on them [13].

In India [25] concluded that 100% of the vegetable crops tested were contaminated. Out of 60 samples, 92% were contaminated with organochlorines, 80% with organophosphates, 41% with pyrethroids and 30% with carbamates. About 23% showed residues of organophosphate insecticides above the respective MRL values. In Mauritius, [10] sampled 115 vegetable and fruit crops and extracted pyrethroids residues. They recorded cypermethrin in 73% of tomatoes, 37% of the watercress and 31% of the beans, whereas deltamethrin was found in 53% of tomatoes and 19% of watercress samples analyzed. In Benin endosulfan, the most commonly used insecticide in cotton, during 1999/2000 growing season, contributed to food poisoning deaths of approximately 70 Benin citizens [38]. Consequently, there was increased demand for chemical free vegetables, which were grown mainly by the application of extract of neem and papaya leaves [38].

In Ghana, high levels of pesticide residues on foodstuffs has led to an outcry over the inappropriate use of pesticides on vegetables cultivated in urban and peri–urban areas [23]. At Kadjebi in the Volta Region of Ghana, five members of a household died after eating okra that was sprayed with an insecticide [6] and in July 2004, several people were admitted to hospital at Tarkwa in the Central Region of Ghana after eating cabbage sprayed with excessive amounts of organophosphates [18].

Research Work reported by many scientists in Ghana have shown concern for the use of chlorpyrifos against pests of food crops. [26] and [2] analysed residues in cabbage and exportable pineapples, respectively. Chlorpyrifos was also detected in 6/8 samples of street vended waakye (rice and beans) and 1/8 samples of fufu (cassava and plantain dough) that were analysed in 1999-2000. [9]showed detectable levels of lindane residues in exportable cocoa beans, but the residue levels were lower than the level permitted by Codex Alimentarius Commission. [32] recorded significant levels of Lindane and endusulfan residues in fish and water, from three rivers that flow through areas of intensive vegetable farming. Higher levels of residues were recorded in fish than in water, indicating accumulation of pesticides in fish. The highest quantities were found in River Oda. The levels of Deltaphos were above recommended MRL [17]. About 33% of cabbage samples assayed showed residue levels, which were 2-3 folds higher than the FAO/WHO MRL levels [17]. While in Volta region a survey of sixty farmers detected the presence of chlorpyrifos, DDT, cypermethrin, and dimethoate in shallots, with levels of chlorpyrifos exceeding the Codex maximum residue level [23]. Similar work by [3] on vegetable samples (lettuce, cabbage and spring onions) from 9 markets and 12 selling points in Accra, Kumasi and Tamale detected chlopyrifos on 78% of the lettuce, lindane on 31%, endosulfan on 36%, lambda- cyhalothrin on 11%, and DDT on 33%. In addition, samples of fruits and vegetables from urban markets in great Accra also showed predominance of methoxychlor in (pineapple, lettuce, cabbage, cucumber and onion), lindane in (papaya, pineapple, cabbage and onion) as well as dieldrin in papaya, banana, pineapple and cabbage. Residues of endrin in lettuce and carrot were higher that the EC MRL, as well as chlorpyrifos on pineapple [8].

These evidences of pesticide residues violations reaffirm the need to minimize pesticide residues in agricultural produce, especially vegetable crops. Such pest management approach requires greater information not only from the field with respect to pest density, location and potential to increase, but also from the pattern of insecticide use [15]. This study sought to establish insecticide use pattern and agronomic practices in cabbage farms which might affect the level of insecticide residues in cabbage.

1. Materials and Methods

1.1 *Study area*

The study was conducted in three localities within Accra Metropolis namely (Dzorwulu, Airport and Madina) in the Greater Accra and Mampong- Akuapem in the Eastern Regions of Ghana (Fig. 1). These sites were chosen because of the differences in agronomic practices of the farmers, rainfall and insecticide use patterns. The global positioning system (GPS) was used to determine the specific geographical coordinates of the sampling sites as follows: Dzorwulu (05^o 37' 05" N 00^o 11' 70" W), Airport (05^o 35' 72" N 00^o 10' 89" W), Madina (05^o 40' 36" N 00^o 10' 24" W) and Mampong-Akuapem (06^o 12' 00" N 00^o 01' 00" W). Accra suburb is located within the greater Accra Region in Southern Ghana. It is a coastal savannah ecological zone, characterized by dry climatic conditions with two peak rainy seasons from April to June and September to October. The annual rainfall ranges between 740 and 890 mm per annum and a temperature range of 26 ^{o}C and 30 ^{o}C and relative humidity of 65-75 % [12]. Mampong-Akuapem on the other hand records the highest mean monthly temperature of 30 ^{o}C between March and April and the lowest of 26 ^{o}C in August. The relative humidity of the area is 65-75% throughout the year and the vegetation consists mainly of grass with isolated patches of shrub and sparse trees. The major rainfall season falls in June–July and followed by a long dry season, the annual rainfall is about 1,270 mm per annum [39]. A sampling site in Accra suburbs is shown in Fig. 2.

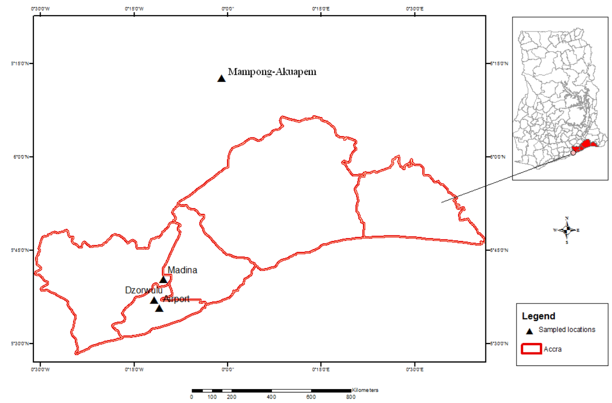

Figure 1. Map showing cabbage sampling sites in Accra Metropolis and Mampong Akuapem

Figure 2. Sample collection site at Dzorwulu, a cabbage farm destroyed by Diamondback moth

1.2 *Survey*

A questionnaire based on [20] was used to obtain information needed for the determination of insecticide type and usage, history of the farms and the prevailing agronomic practices. The questionnaire was structured to suit the farmers understanding, and they responded to the questions in the presence of an administrator who helped to translate the questions into the local language in some cases, or to further simplify the questions. The data obtained was analysed with a view to making a decision on the appropriateness of the site for sample collection and the most commonly used insecticides to be selected for the study. A reconnaissance survey was carried out to guide the planning and conducting of the formal survey [35]. Locating cabbage farms for the survey was difficult and perennial cabbage growers, extension officers, pesticide sellers, grocers and friends were approached for information on where to find more growers. The choice of farmers from a particular cabbage growing area depended on the number of growing areas identified from the informal survey and the number of growers in a particular area. In each growing area, 10 cabbage growers were randomly selected and interviewed.

1.3 *Insecticide Residue Levels in cabbage*

The level of insecticide residues was determined using marketable cabbage heads from the randomly selected cabbage farms as well as from the screen house-grown insecticide-free cabbage which served as control. Farms were selected based on the level of infestation of pests, the most commonly used pesticides and farmer's agronomic practices like watering. A composite of cabbages collected from 2-4 fields within a radius of 2-3 km with related insecticide use patterns served as the sample for each location. After selecting the farms, sampling was only done when the farmers were harvesting their cabbage for sale. This precaution was necessary to ensure that cabbage heads selected were ready for sale and for consumption. To randomize the cabbage head sampling, the field was mapped on a piece of paper, and numbers given to rows of plant and each plant in each row. The numbers of the rows were balloted for before picking ballots for plants in each row and the particular heads harvested were kept in polythene bags. The cabbage heads were sliced longitudinally into cone shapes and 50 grams of each sample was weighed into labelled beakers, and then transferred into a conical flask and 25 ml hexane was added, and then was stored at 4 ^{0}C for residue extraction.

1.4 *Analysis of insecticide residues*

Fifty grams of each sample was blended in three 40 ml portions of hexane-butanone mixture (5:1) at a minute interval, for 4 minutes at each instance, and the extract decanted into a 250 ml flask. The homogenate was centrifuged in a bench top centrifuge at 3000 rpm (rotor radius, 11.5 cm) for five minutes at room temperature. The pooled extracts were concentrated using the Rotary Vacuum Evaporator to about 2 ml, transferred into a 10 ml vial, dried under nitrogen gas and then re-dissolved in 5 ml hexane.

1.5 *Solid phase extraction (SPE)*

The crude extract was also subjected to solid phase extraction (SPE) in Alltech Prevail C_{18} solid phase extractor (SPE). One milliliter aliquots of the extract were dried under nitrogen and used for solid phase extraction. After equilibration of the SPE first with methanol (2 ml), the sample was taken up in hexane (0.5 ml) and eluted with 2 ml each of methanol, ethyl acetate, and hexane in that order to recover the cleaned insecticide residues in order of polarity. Eluted fractions collected, dried under nitrogen to obtain the weight of residue recovered. The residues were re-dissolved in appropriate volumes of eluted solvents to give stock sample concentrations of 10 mg/ml, aliquots of which were used for brine shrimp toxicity bioassay.

1.6 *Brine shrimp bioassay of cabbage extracts*

1.6.1 *Hatching of Brine shrimps*

The Brine shrimps eggs used for the bioassay were obtained from Brine Shrimp Direct, California, USA. The brine shrimps eggs were hatched in a saline solution of concentration 25 g/L which was used to fill a small-perforated dividing tank (about $\frac{3}{4}$ full). The brine shrimp hatchery was improvised from a soap dish, about a half portion of the cover was cut off and a

piece of plastic divider was used to shield the eggs from light while allowing the hatched nauplii to swim there. A spatula was used to transfer the brine shrimp eggs to the covered half of the tank, the other half of the tank being open, allowed the shrimps to move towards light after hatching. The hatching tank was left under fluorescent light at 22 ^{o}C for 48 hrs before brine shrimp nauplii were used for the bioassay. A modified methodology outlined by [28] was adopted.

1.7 *Calibration curves for standard insecticide*

A preliminary bioassay was done to determine the concentration that gave 10% and 90% mortality. The following serial dilutions of the standard insecticides at 10 μg/ml stock concentrations were tested to obtain standard curves and the LC_{50}: 500 ng/ml, 50 ng/ml, 5 ng/ml, 0.5 ng/ml for chlorpyrifos-methyl, permethrin, deltamethrin, cypermethrin and 1.0 μg/ml, 100 ng/ml, 10 ng/ml and 1 ng/ml for lambda-cyhalothrin and pirimiphos-methyl. The appropriate dilutions of the stock solution in hexane were dried under nitrogen, taken up in acetone (40μl) and about 5 ml of sea-salt water containing brine shrimp nauplii was added. A control containing acetone (40 ml) but no insecticide was also set up. Four replicates of each insecticide standard and control were bioassayed. Mortality data was recorded for each dilution and the control. The data were analysed using probit package in MINITAB 12 windows software to determine LC_{50} and LC_{95}, and the curves were obtained for all the standard insecticides. The Abbots formula [1] was used to correct for deaths in the control samples. The corrected percentage mortalities were used to estimate the concentration of insecticide residues in cabbage, from the linear regression equation of dosage–mortality curves of the standard insecticides.

1.8 *SPE elution sequence of standard insecticides*

In order to determine the elution sequence of the standard insecticides from SPE, 100 μl of each of the standard insecticides was applied to the methanol equilibrated SPE tubes and then eluted with 2 ml each of methanol, ethyl acetate and hexane and fractions collected, dried and bio-assayed for brine shrimp toxicity as described earlier.

2. Results

2.1 *Agronomic practices of cabbage farmers*

The survey revealed that all the cabbage growers visited were small-scale farmers since 47% of the farms cultivated were less than $\frac{1}{2}$hectare (ha); 23% were about a hectare; 23% were 1-2 ha. and only 7% of the farms were more than 2 ha in size. Most of them were perennial cabbage farmers since 36% of the farmers had been involved in cabbage production for a minimum period of 5-10 years. About 34% of the farms have been cultivated continuously for 11-20 years or more. The main equipment mostly used for irrigation on the farms by 70% of the farmers was watering can, bucket and cup by 13.3% and10% used water hose. The watering can was fitted to the shower type nozzle by only 9% of the farmers, while the rest fitted flat metal plate.

2.2 *Pests and pest control*

About 93% of the farms surveyed had serious problem with insect pest infestation and over 73% of the farmers reported that DBM was the most serious and destructive pest of cabbage in the farms. Chemical control was the most predominant method used by 97% of the farmers to control pests while a few practiced IPM.

2.3 *Insecticides and their use pattern*

The most widely used insecticides to control cabbage pests in the study areas during the survey period and those used previously are shown in Tables 1 and 2. When all the insecticides were grouped into their various classes, the results showed that apart from growth regulators, the use of organophosphates was on the rise (Fig.3). On the contrary, pyrethroids and the biopesticides: (B.t. formulations; Biobit and Dipel) usage has declined over the years. About 66.67% of the farmers attributed the decline in the usage of these insecticides to ineffectiveness against the target pests while 26.7% of the farmers said the chemicals were out of stock, compelling them to look for other alternatives. Some of the farmers also stopped using them because the chemicals were too expensive. The insecticides were either sprayed alternatively by 63.3% of the farmers or applied as cocktail mixtures by 36.7% of them. The various combinations of insecticides used by growers were as follows:

i Regent and Rimon [insect growth regulators]

ii Dize DDV [organophosphate], Rimon [insect growth regulators] and Cydimsuper [pyrethroid + organophosphate]

iii Regent [insect growth regulators] and Dursban [organophophate]

iv Cydim super [pyrethroid + organophosphate] and Dursban [organophosphate]

vi Rimon [insect growth regulator] and Deltapaz [pyrethroid]

vii Rimon, Regent [insect growth regulators] and Dize DDVP [organophosphate]

The majority of the respondents used the lid of chemical containers as standard measure of dosages and for Dipel, in Mampong, farmers used matchbox. However, dosages in the farms were difficult to estimate because the application equipment was not calibrated before use. The main mode of application was manually operated knapsack sprayer. During spraying exercise 60% of the growers did not wear any protective clothes during spraying while 26.67% were partly protected by using gloves and facemasks and only 13.33% wore full protective clothing.

Table 1. Current insecticide use pattern in some suburbs of the Accra Metropolis and Mampong-Akuapem.

Agrochemicals	Class	Total (%) usage
Rimon	Growth regulator	32.39
Regent	Growth regulator	19.72
Dursban	Organophosphate	9.86
Dize DDVP	Organophosphate	7.04
Cyperdim super	Pyrethroid+organophosphate	5.63
Dipel	Biopesticides	4.23
Pawa	Pyrethroid	2.82
Amektin	Growth regulator	2.82
Others*	1-5=Pyrethroids 6-9=Mixtures (Sps+Ops)10=Biopesticide	12.68

*Karate[1], Cypercal[2], Deltpaz[3], Deltaplan[4], Decis[5], Actelic[6], Cyperphos[7], D336[8] and Polytrine[9], Biobit[1]0

Table 2. Previous insecticide use pattern in some suburbs of the Accra Metropolis and Mampong-Akuapem.

Agrochemicals	Class	Total (%) usage
Dipel	Biopesticide	18.18
Karate	Pyrethroid (SP)	18.18
Biobit	Biopesticide	12.73
Regent	Growth regulator (IGR)	10.91
Cymbush	Pyrethroid (SP)	7.27
Polytrine	Mixture (Op + SP)	5.45
Cydimsuper	Mixture (Op + SP)	5.45
Actelic	Mixture (Op + SP)	5.45
Orthine	Pyrethroid (SP)	5.45
Dursban	Organophosphate (OP)	3.64
Others*	1=Mixture, 2=IGR	7.27

*Cyperphos[1], Rimon[2], Neem[3] and Thionex[4]

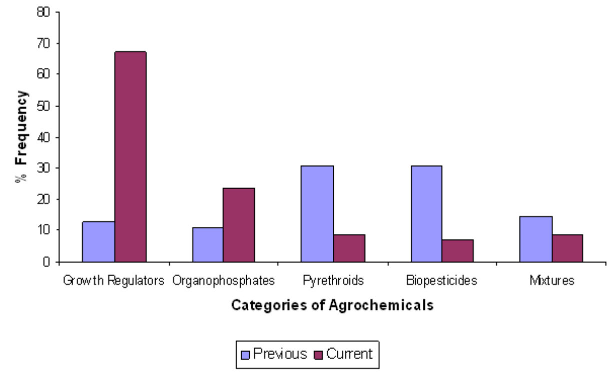

Figure 3. Comparison between the previous and currently used agrochemicals in the cabbage farms

2.4 *Frequency of insecticide application*

The interval between insecticide spraying and irrigation varied greatly among the cabbage farmers. About 33% of them watered within the same day of insecticide spraying while 53% allowed 1-3 days interval and 3% more than 5 days interval (Fig. 4). The growers also sprayed the insecticides frequently and at short intervals with 70% of them spraying at a frequency less than a week (Fig. 5). This high frequency of spraying was reflected by 46% farmers who observed pre-harvesting interval (PHI) as short as less than a week (Fig. 6). In addition, some of the farmers during heavy pest infestation could spray the cabbages and sell them immediately.

The improper use of insecticides could be because the farmers obtained professional advice on the use and handling of insecticides from fellow farmers and pesticide dealers. Only 36% of them received advice from Agricultural Extension Agents and of this number 10% were visited within 1-2 weeks, while 10% of them received their visits well above two years span and for some the visits were very irregular and others were not visited at all (Fig. 7). With regards to insecticide residue awareness, 63. 33% had no idea about it (Table 3). The majority (82%) had heard about the perceived risks caused by improper use of insecticides through the mass media (Fig. 8).

Table 3. Farmers' Awareness about some agronomic practices and insecticide residue

Practice/problems	Yes	No
Pest problem	93.3	6.7
Nursery treatment	86.7	13.3
Keeping of farm records	16.7	83.3
IPM training	16.7	83.3
IPM application	13.3	86.7
Residue awareness	36.7	63.3

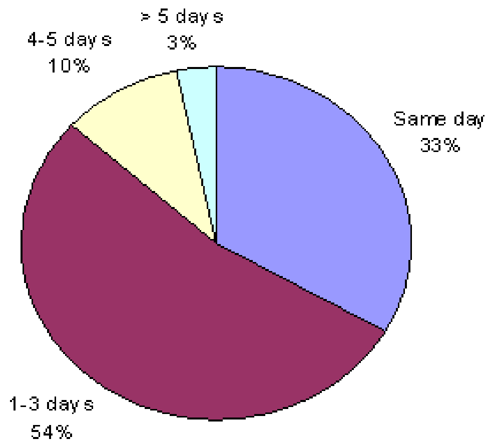

Figure 4. Interval between spraying and subsequent irrigation

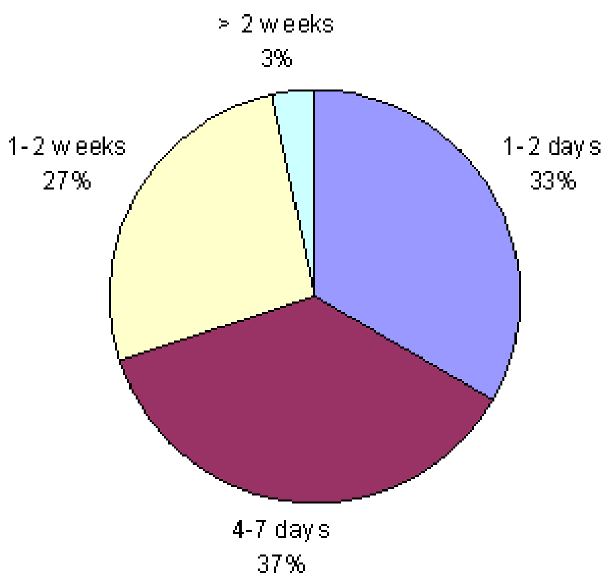

Figure 5. Frequency of insecticide spraying

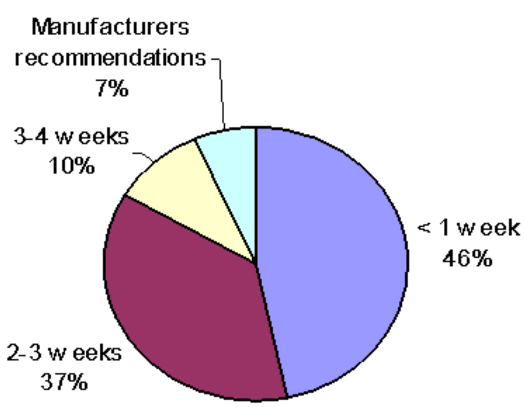

Figure 6. Pre-harvest interval observed by cabbage farmers

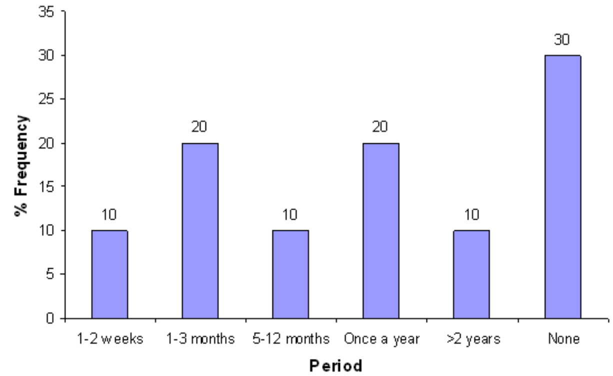

Figure 7. Frequency of visits by the extension officers

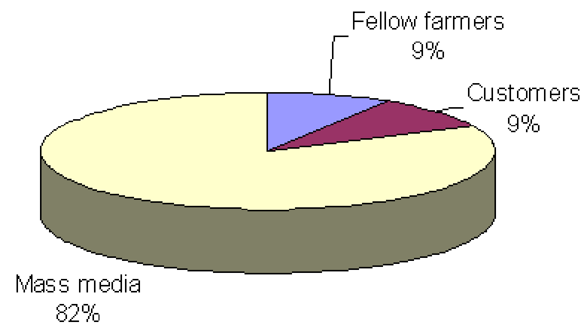

Figure 8. Sources of information on insecticide residues awareness

2.5 Residue Level estimation

2.5.1 *Brine shrimp bioassay for the insecticide SPE standards fractions*

Mortality data recorded following bioassay of SPE fractions obtained by elution of the standard insecticides (permethrin, cypermethrin, deltamethrin, lambda-cyhalothrin, chlorpy-rifos-methyl and pirimiphos-methyl) using methanol, ethyl acetate and hexane are shown in Fig. 9. It was observed that pyrethroids were mostly eluted in hexane fractions, chlopyrifos-methyl in methanol and pirimiphos-methyl in ethyl-acetate. Dose-response mortality curves of the insecticide standards were obtained from probit analysis and their LC_{50} and LC_{95} values and the slopes of the curves were recorded as shown in Table 4. The potency of pyrethroids based on LC_{50} was as follows: cypermethrin > permethrin > deltamethrin > lambda-cyhalothrin. For organophosphates, chlorpyrifos was three times as potent as pirimiphos-methyl.

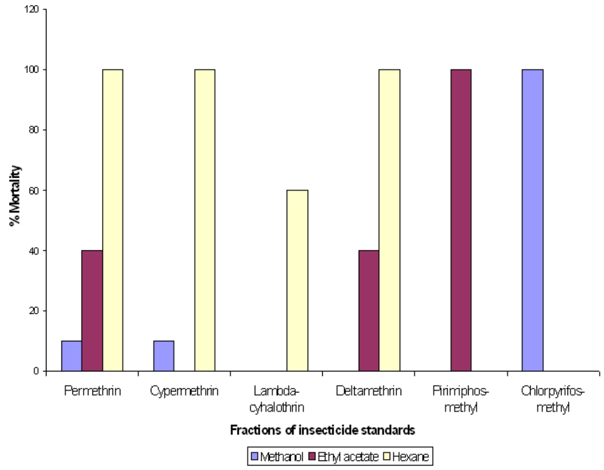

Figure 9. Brine shrimp mortality profile of SPE fractions of insecticide standards

2.6 Estimation of residue levels in cabbage samples

The differential elution of the two organophosphate standards and pyrethroids from SPE with methanol, ethyl acetate and hexane were used as basis for fractionation of these insecticides from extracts of the residues obtained from cabbage. To estimate insecticide residue content in the different fractions, regression equations for standard insecticide concentration against brine shrimp probit mortality calibration curves were used (Figs. 10-12). Calibration curve of chlorpyrifos-methyl was used for methanol fractions, while pirimiphos-methyl and cypermethrin were used for ethyl acetate fraction and hexane fractions respectively.

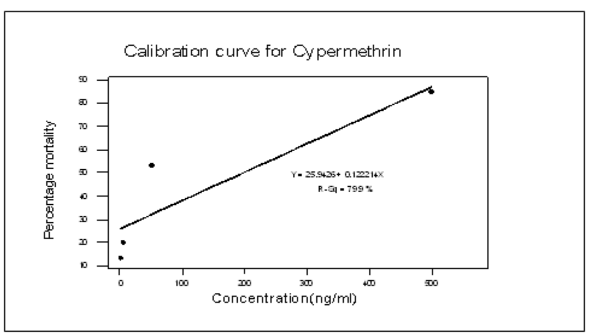

Figure 10. Residues Analysis (Calibration Curves)

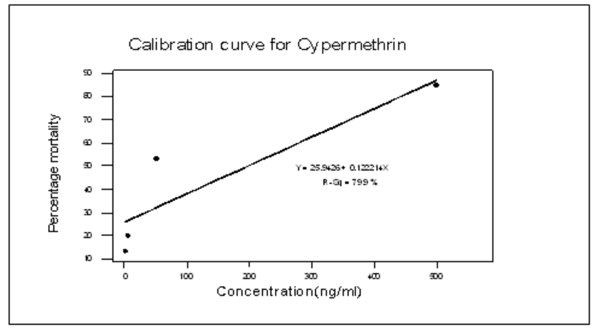

Figure 11. Residues Analysis (Calibration Curves)

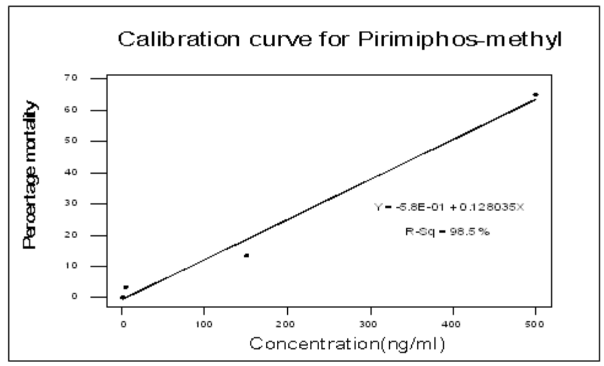

Figure 12. Residues Analysis (Calibration Curves)

2.7 Brine shrimp mortality profile for SPE fractions

Figure 13 shows biological activity recorded for fractions obtained from all samples using the three selected solvents in the order: methanol, ethyl acetate and hexane. High mortality (42-93%) was generally recorded for methanol fractions. The ethyl acetate and hexane fractions gave higher mortality in the Dzorwulu samples than for Airport and Madina. Mortality in ethyl acetate and hexane were lower for Mampong samples.

2.8 *Maximum Residue Levels (MRL) of insecticides in the cleaned cabbage extracts.*

The results showed high values for chlorpyrifos-methyl in all the study sites (Table 5). The highest value was recorded in Mampong (124.1 mg/kg). Airport B and the Madina samples recorded 114 mg/kg and 111.5 mg/kg, respectively with the least MRL value recorded in Airport A (55 mg/kg). However, there was no significant difference in MRL means for the study sites. For pirimiphos-methyl, cabbage samples from Dzorwulu sites recorded the highest values (14.6 mg/kg and 10.9 mg/kg). The MRL value for Dzorwulu A was significantly different from all the sites. Moderate MRL values were recorded for the Madina and Airport cabbage samples and the least value was recorded in Mampong-Akuapem.

Estimation of brine shrimp lethal activity of hexane fraction eluents was difficult due to the low mortalities recorded hence concentrations of pyrethroids was detectable only in Dzorwulu and Airport B. The values were between 1. 2 and 1.

8 mg/kg. Cabbage samples from Dzrowulu were found to have high concentrations of both pyrethroids and pirimiphos-methyl, while Airport samples had comparatively high residue of all the three insecticides. Mampong-Akuapem cabbage samples recorded the highest concentration of chlorpyrifos but the least in pirimiphos-methyl. The pyrethroids levels in the samples were too low to be detected.

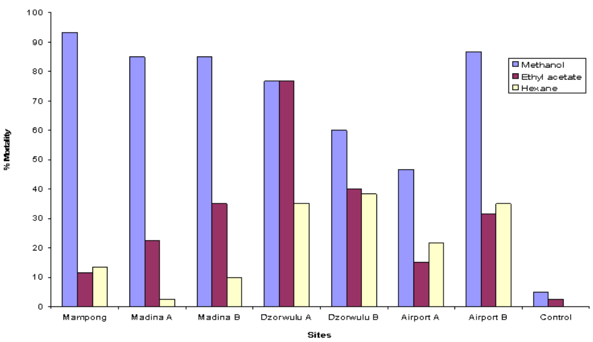

Figure 13. Brine shrimp mortality profile of solid phase extracted fractions from cabbage samples.
*Control – insecticide free cabbage grown under screen house environment.
N/B A total of 60 Brine shrimp nauplii were used for each fraction of the sample extract while a total of 40 brine shrimps were used for each of the control fractions

3. Discussion

The survey showed that insect pests were a major constraint to cabbage production and the Diamondback moth was considered a key pest of cabbage in Ghana causing damage in 73% of the farms surveyed, this was also confirmed by [7]. The DBM has been reported as a key pest of cabbage and other crucifers in many other parts of the world [29, 19]. The increasing pest infestation could be attributed to improper agronomic practices in the farms. Monoculture enhanced pest infestation on cabbage by lepidopterous insects and aphids since it creates conducive environment for particular insect pest to flourish [24]. In this study, creating a host free period was difficult due to lack of coordination of activities amongst the growers with the result that growers cultivate cabbage at different times of the year. Consequently, growers were unable to synchronize time for insecticide spraying schedules, resulting in unsprayed cabbage plants serving as refuge at a time when some farmers would have sprayed their crops.

Since Brassicas (cabbage, cauliflower and chinese cabbage) have similar pest spectrum [19], all year round cultivation of these varieties of Brassica in adjacent plots to cabbage may bridge the gap in host plant sequence of DBM [29]. In addition, DBM survive on host residues left on the farms or thrown at the side of the farms during off seasons. These practices make food available to the pest, and create favourable conditions for their survival, development and multiplication even during off seasons, leading to increased pest infestation and damage.

On pest control growers relied exclusively on the use of insecticides, [7] also noted that 90 % of famers applied pesticides for pest control. The high rate and dosages of application lead to development of resistance in the pest. Consequently, the survey showed a decline in the use of pyrethroids and the *B. thuringiensis* which were the most widely used against pests of cabbage [30]. The use of organophosphates had instead increased, with a worse consequence due to their persistence in the environment. This could enhance development of resistance due to prolonged exposure to the pest and also cause health hazards due to insecticide residue in cabbage heads.

Cabbage farmers were using pesticides labelled in French (cyperphos, Polytrine, D336 EC and Thionex). These could be a major source of hazards to consumers since the relevant information on the products label concerning safety, recommended dosages and effective use of these insecticides were written in French. Furthermore, these products were not registered in Ghana contrary to the pesticide Control and Management Act, 528 of Ghana. [11] reported that about one third of chemical products on the shelves in a shop in Kumasi were labelled in French. In addition, products that were recommended for use in cotton, coffee and cocoa were sold for use on all crops. For example Akate master (bifenthrin), Confidor (Imadaclopride + thiamethoxam) and Cocostar (bifenthrin + primiphosmethyl) not recommended for vegetables were used [4]. [34] also reported that farmers in Dzorwulu were using organochlorines including those banned for use in Ghana like Lindane, Endosulfans and DDT.

This work confirmed findings by [4] that 61% of farmers mixed two or more pesticides without considering their compatibility or active ingredients. The use of insecticide mixtures leads to simultaneous development of pest resistance because each compound seems to develop the residual inheritance of the supporting genome for resistance in the other [27]. In addition the use of sub lethal dosages enhanced resistance development in DBM, which is capable of quickly developing resistance to all insecticides exposed to it [29].

Concerning personal protection against contamination, only 13. 33% of the farmers wore full protective clothing during spraying, claiming that they were expensive and uncomfortable. Thus, growers were predisposed to the risk of insecticide poisoning, “the New Developing World Disease” [5]. Most of their knapsack sprayers often leaked and it was common for the sprayers to have skin rashes, headaches, and dizziness for a few days after insecticide application [11]. This disregard for human health safety measure was attributed to low level of education by majority of vegetable farmers [33].

Farmers observed short Pre-harvest intervals. Indeed during heavy infestation, farmers sprayed and harvested their produces for sale the same day. [4] also noted that 79% of cabbage farmers in Ashanti region continued spraying during harvesting period. This exposes consumers to great health risk. This was worsened by the observed increase in the use of Organophosphates which require 21 days pre-harvest interval

(PHI). This explains the high residue levels of chlorpyrifos in the cabbage heads analyzed. The use of biopesticide such as *B.t.* should therefore be encouraged towards maturation of cabbage since its PHI is zero days [36] and have less health hazards. More extension education should be encouraged in conjunction with the Farmers Field Schools approach, which was reported to have reduced indiscriminate use of insecticides [22]. Farmers also turned to pesticide sellers and fellow farmers for professional advice concerning identification of new pests and their control. The pesticide sellers are usually interested in marketing their products irrespective of their health and environmental hazards. Fellow farmers would normally recommend insectidices they had successfully used on their farms, although their practices in terms of rate of application and safety measures were inappropriate. Most of the respondents (63%) were ignorant about perceived risks caused by improper use of insecticides. They attributed pesticide-poisoning incidences to lack of proper training on insecticide use since the farmers were reported to have used insecticides meant for cocoa on cabbage farms. [31] attributed poisoning cases among farmers to inappropriate practices in handling and use of pesticides.

Brine shrimp toxicity bioassay SPE directed fractionation of extracted residues from cabbage was used to establish the identity and levels of organophosphates and pyrethroids residue levels in cabbage samples. Mampong cabbage samples, gave significantly high chlorpyrifos residues and consequently MRL, but the lowest levels of pirimiphos-methyl and pyrethroid residues. The survey showed that the farmers were currently using chlorpyrifos (dursban) justifying the high chlorpyrifos residues detected.

Unlike Mampong, the Accra suburb sites gave much higher yield for all the three insecticides. Notably Dzorwulu A had significantly higher amounts of pirimiphos-methyl and detectable levels of pyrethroid residues. Similarly, Airport samples showed high levels of pyrethroids residues. This was substantiated by the insecticide use pattern in the survey, which indicated the use of most of the insecticides chosen for the residue estimation. Similar results were reported by [16], who showed that 54.2 % of vegetables samples from farms along Onyansia stream in Accra municipality had residues above the recommended MRL.

The generally low residual activity and MRL for pyrethroids could partly be explained by the fact that pyrethroids are photosensitive and are therefore less persistent in the environment compared to the OPs. However, comparing these findings with the work of [30] on lambda-cyhalothrin, there was 18 fold increase in MRL values at Dzorwulu B and 13 and 12 fold increase in Dzorwulu A and Airport B, respectively. This is 6 to 9 fold above the FAO/ WHO MRL of 0.2 mg/kg. The residue levels of pirimiphos-methyl gave 2-15 fold increase above the recommended MRL of 1 mg/kg. Chlorpyrifos residue recorded 55 to 124 fold increase above the recommended MRL of 1 mg/kg recommended by Codex Alimemntarius Commission.

The insecticide use pattern survey also showed an increase in the use of organophosphates and a reduction in the use of pyrethroids (Fig. 3) hence the high chlorpyrifos residues recorded. Residue levels on cabbage heads have become a great source of health hazards to cabbage consumers in Ghana. Hence the need to produce healthy-looking damage-free vegetable crops and to minimize the pesticide residues in vegetable crops is the greatest challenge for better economic gain from cabbage production. To achieve this, insecticide companies and researchers should educate farmers on proper use and handling of insecticides. This should include choosing short persistent insecticides which should be used judiciously at the recommended effective dosages and frequencies. Alongside, IPM approach which relies on the use of environmentally friendly insecticides, cultural practices coupled with the use of parasitoids should be encouraged. Measures should be put in place to ensure that farmers use the right equipment and in good conditions for watering and spraying for effective control of insect pests as well as for their personal protection during these exercises. In addition, the Environmental Protection Agency of Ghana should prevent the importation of insecticides not registered for use in Ghana. The National Agricultural Extension Service should be strengthened since the extension service's education of cabbage farmers was found to be very weak.

Table 4. Lethal concentrations of insecticide standards

Insecticides	LC_{50} (mg $litre^{-1}$) (95% CI)*[a]	LC_{95} (mg $litre^{-1}$) (95% CI)*[a]	Slope
Deltamethrin	374.0	970.4	0.032
	(286.9-524.7)	(749.1-1411.9)	0.032
Cypermetherin	179.7	634.0	0.019
	(108.1-293.1)	(459.4-1053.5)	0.019
Pirimiphos-mehyl	684.1	1420.8	0.015
	(483.9-1269)	(982.3- 2805.8)	0.015
Lambda-cyhalothrin	561.3	1413.6	0.019
	(422.9- 64.5)	(116.8- 1960.3)	0.019
Chlorpyrifos-methyl	222.0	489.2	0.067
	(177.1- 284.7)	(402.0-628.1)	0.067
Permethrin	234.7	766.3	0.037
	(171.3- 327.9)	(596.9-1089.8)	0.037

*[a]CI is the confidence interval

Table 5. Fractionated Insecticides from cabbage samples and estimated insecticide residue level

Site/Sample	Insecticide fractions	Total cleaned residue (g)	% Mortality	Total Active residues (mg) × 10-3	% Active residues	Residual activity	MRL (mg/kg) of cabbage
Mampong	Chlorpyrifos	31.8	93.3	488.5	0.02	124144.1	124.1
	Pirimiphos	2.7	11.7	95.7	0.004	2086.3	2.1
	Pyrethroids	1.7	13.3	ND*	ND*	ND*	ND*
Madina A	Chlorpyrifos	31.6	85	441	0.018	111524.5	111.5
	Pirimiphos	4.4	22.5	180.3	0.007	6400.7	6.4
	Pyrethroids	2.7	2.5	ND*	ND*	ND*	ND*
Madina B	Chlorpyrifos	31.6	85	441	0.018	111524.5	111.5
	Pirimiphos	2.6	35	277.9	0.011	5835.9	5.8
	Pyrethroids	5.8	10	ND*	ND*	ND*	ND*
Dzrowulu A	Chlorpyrifos	31.5	76.7	393.5	0.016	99022.7	99
	Pirimiphos	3	76.7	603.3	0.024	14640.1	14.6
	Pyrethroids	2.1	35	74.1	0.003	1266.1	1.3
Dzrowulu B	Chlorpyrifos	31.1	60	298.5	0.012	74373.7	74.4
	Pirimiphos	4.3	40	316.9	0.013	10922.5	10.9
	Pyrethroids	2.2	38.3	101.4	0.004	1804.9	1.8
Airport A	Chlorpyrifos	30.9	46.7	222.5	0.009	54994.9	55
	Pirimiphos	3.4	15	121.7	0.005	3334.6	3.3
	Pyrethroids	1.4	21.7	ND*	ND*	ND*	ND*
Airport B	Chlorpyrifos	31.6	86.7	450.5	0.018	114038.7	114
	Pirimiphos	3.4	31.7	251.9	0.01	6818.1	6.8
	Pyrethroids	2.1	35	74.1	0.003	1235	1.2
Control*c	Chlorpyrifos	30	5	ND*	ND*	ND*	ND*
	Pirimiphos	1.6	2.5	ND*	ND*	ND*	ND*
	Pyrethroids	1.2	0	ND*	ND*	ND*	ND*

*c Control- Insecticide free cabbage samples grown in the screen house.

*a Active residue- the estimated concentration (μ) of toxic residues per solvent using the calibration curves of the insecticide standards

*b % active residues- This is the fraction of the active residue in relation to the total residues extracted from the cabbage heads.

N/B Active residues for mortalities below 26% of pyrethroid fractions could not be estimated from the calibration curves of the insecticide standards

4. Conclusion

Poor agronomic and insecticides application practices by cabbage farmers have increased pest infestation on cabbage in Ghana. Consequently, there is an increase in the rate and frequency of insecticide application resulting in high levels of insecticide residues in cabbage as shown in Brine shrimp toxicity test. Chlorpyrifos and pirimiphos-methyl levels were far higher than the recommended FAO/WHO established MRL levels. Likewise pyrethroids levels compared to the works of earlier scientists and recommended MRL had also increased. The results of the present study have shown that the insecticide residue problem for cabbage should be taken seriously in Ghana and urgent steps must be taken to help farmers control insect pests of cabbage without compromising human health.

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